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Review Article

Understanding the Antinutritional Factors and Bioactive Compounds of Kodo Millet (*Paspalum scrobiculatum*) and Little Millet (*Panicum sumatrense*)

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Kodo and little millet (Kutki) have a variety of phytochemical constituents including derivatives of hydroxybenzoic acid and hydroxycinnamic acids, myricetin, catechin, luteolin, apigenin, daidzein, naringenin, kaempferol, and quercetin with vast health benefits and thus can be utilized as functional food ingredients. Millet-based foods and their food products have physiological and health-promoting impacts, notably antidiabetic, anti-obesity, and cardiovascular disease, and based on the actions of phytochemicals, it plays a major role in the body's immune system. However, antinutrients (tannins, oxalate, trypsin inhibitor, and phytates) present in these millets restrict their utilization since these factors bind the essential nutrients and make them unavailable. Therefore, this review suggested overcoming the effects of antinutrients in these millets, thereby opening up important applications in food industries that may promote the development of novel functional foods. Various methods were discussed to eliminate the antinutrient factors in these millets, and hence, the review holds immense significance to the food industry for effectively utilizing these millets to develop value-added RTE/RTC products/functional food/beverages.

1. Introduction

In today's scenario, malnutrition and food security are burning topics around the globe. As the population increases day by day, it becomes very important to address these issues to maintain the food balance among all. Millets, despite their therapeutic properties and agro-economic potential, fall under the umbrella of "underutilized," "forgotten," or "orphan" crops due to their coarse character and minimum usage in convenience foods along with poor research and novel techniques for the development of food products [1, 2]. Millet grains are also called "famine reserves" as they could be stored up to two years or more [3]. Millets are considered among the sixth most important cereals with reference to production after rice, wheat, corn, sorghum, and barley [4].

The world's highest production of millets is in India [5]. According to a report by the International Crops Research Institute for the Semi-Arid Tropics, the Consultative Group for International Agricultural Research for Millets (2016) states that 50% of the millet production is the pearl millet, which serves to be a source of food and income to 90 million people. Millets are sown and produced in countries of warm and tropical regions such as Africa, Asia, Eastern and

Southern Europe, and some parts of America. the total area for the production of all types of millets is nearly equal in both Africa and Asia. However, Asia is proportionately higher than Africa in terms of production. Ref. [6] mentioned that 80 countries produce millets but 90% production happens in 13 countries only, where India tops the list by producing 41% of pearl and finger millet for global supply, which is three and half times higher than Nigeria on an average of just 25% of land. The improved and hybrid varieties of the millets have largely led to this increased production in India [4]. According to FAO, the average annual millet production was 28.3 million tonnes along with 0.9 tonnes/ha average yield in 2014 [7], whereas in 2018, overall millet production in the world was roughly around 31,019,370 tonnes [6].

Millets are a type of small-seeded grasses that are commonly farmed as cereal crops or grains for human sustenance and fodder around the world [8]. The advantages in using the crop, such as production and brief season period, capable of withstanding dry and extreme weather conditions of 64°C with low rainfall of 350–400 mm annually [9], and poor irrigation facilities, have gained popularity, leading it to be a drought-resistant plant. This could be owing to their efficient photosynthetic system, which is due to the fact that they are C4 cereals with only 6–8 weeks of maturity period for seeds [10]. Millets are crops with unique features that grow under robust and competing conditions and with efficient usage of available resources, and are adaptable to cultivation circumstances. The key evolutionary alteration that affects these features is the C4 cycle of CO_2 metabolism. C4 plants have higher CO_2 absorption rates in bright sunlight above 30°C and are superiorly photosynthetically acclimated to nonshaded tropical environments, giving them an advantage over other crops in hot temperatures [11]. Therefore, millets have a tendency of tillering, a phenomenal rejuvenating capability, and recover quickly if moisture stress circumstances are removed. Such millets are cultivated using conventional techniques, and no pests are attracted to them (called pest-free crops). The preponderance of them is also unaffected by pests found during storage. As a result, they have less need for insecticides and pesticides and thus aid huge help to the agricultural and industrial sector [3].

Among the many of its properties, one characteristic is being gluten-free, which helps patients in curing celiac disease and gluten allergy [12]. They are nutricereals, highly nutritious on the basis of protein, dietary fiber, vitamins, and minerals as shown in Tables 1 and 2. Millets in comparison with other cereals like rice and wheat have 60–70% carbohydrates, 1.5–5% fat, 6–10% protein, 2–4% minerals, and 12–20% dietary fiber, along with other phytochemicals and amino acids [16]. Table 3 shows the essential amino acid profile for millets in comparison with wheat and rice. The concentrations of nutritional values change according to the variety of millets and cultivars and also depend on the climatic conditions for their growth [17]. Despite being rich in nutrients and having numerous health benefits, traditionally millets have been used as animal feed and remain unavailable for consumers due to scarcity for the development of functional food or ready-to-use goods.

Millets are eaten in various parts of the world, such as Russia, Poland, and China, in different forms (porridge or congee). Millet is a staple food for the Namibian people. Sudanese pancakes made from pulverized millet are well known. Millet flour is consumed as porridge and served with mixed vegetables and a meat sauce in Senegal, whereas in Pakistan, it is eaten as a cuisine in the form of chapatti, and in India, it is consumed as khichdi, idly, and chapatti. Commercial meals made from millet include noodles, millet juice, and puffed millet [9].

Although millets are rich in nutrients such as crude protein, crude lipid, and crude fiber, their mineral contents are not available as the minerals are bounded mainly by the antinutrient substances and the minerals (phosphorus and iron) become biologically unavailable. Therefore, various techniques have been utilized to degrade the content of antinutrients in the millets such as soaking, dehulling, cooking, and fermentations. Since the presence of these antinutritional factors is high in concentration among kodo and little millets, it is important to reduce these factors before moving on with the production of any ready-to-eat food product. Therefore, in this review, parameters that overcome the antinutritional components are discussed, which could provide benefits to the food industry to develop nutrient-rich functional food and nutraceuticals, especially from the kodo and little millets.

2. Indian Origin (Kodo and Little) Millets

Over the years, millets have enjoyed the tag of "poor man's food grain" because of their sheer affordability. Millets have been classified into two groups on the basis of their grain size—major millets and minor millets. Major classification includes pearl millet (*Pennisetum glaucum*), foxtail (*Setaria italica*), proso (*Panicum milliaceum*), and finger (*Elusine coracana*) millets [18] whereas the minor ones being the kodo millet (*Paspalum scrobiculatum*), little millet (*Panicum sumatrense*), barnyard millet (*Echinochloa frumentacea*), fonio (*Digitaria exilis*), and teff (*Eragrostis tef*) millets [19] that belong to the family Poaceae and kingdom Plantae.

Kodo millets are the coarsest and digestion-friendly millets (Figure 1). It is an ancient millet grain that originated in tropical Africa and was domesticated in India some 3000 years ago [20]. Indian Crown Grass, Native Paspalum, Ditch Millet, or Rice Grass are a few names by which kodo millet is known. In India, it is also known as Kodra and Varagu. India, Pakistan, the Philippines, Indonesia, Vietnam, Thailand, and West Africa are among the countries that cultivate millets. It serves as the major source of food in the Deccan Plateau of Gujarat, India. The kodo millet is mainly grown in various parts of India such as Madhya Pradesh, Andhra Pradesh, Tamil Nadu, Uttar Pradesh, Bihar, Maharashtra, Gujarat, and Orissa. Madhya Pradesh accounts for 33.4 percent of India's land area and 26.6 percent of the country's small millet production. In Madhya Pradesh, kodo (70%) and little (24%), together, contribute to

Table 1: Proximate composition of millets compared to cereals.

Cereals and millets	Parameters						
	Moisture (g)	Protein (g)	Fat (g)	Ash (g)	Carbohydrate (g)	Energy (KJ)	Total dietary fiber (g)
Kodo millet	14.23	8.92	2.55	1.72	66.19	1388	6.39
Kutki/Little millet	11.36	10.13	3.89	1.34	65.55	1449	7.72
Proso millet	11.9	12.5	1.1	1.9	70.4	341 (Kcal)	0
Finger millet	13.1	7.3	1.3	2.7	72	328 (Kcal)	11.5
Foxtail millet	11.2	12.3	4.3	3.3	60.9	331 (Kcal)	2.4
Barnyard millet	11.9	6.2	2.2	4.4	65.5	307 (Kcal)	1.98
Pearl millet	12.4	11.6	5	2.3	67.5	361 (Kcal)	11.3
Whole wheat flour	11.1	10.57	1.53	1.28	64.14	1340	11.36
Rice (raw) milled	9.93	7.94	0.25	0.56	78.24	1491	2.81

Source: Gopalan et al. [13]; Geervani and Eggum [14]; Longvah et al. [15].

Table 2: Vitamin and mineral profile of millets compared to cereals.

Cereals and millets	Parameters										
	Thiamine B1 (mg)	Riboflavin B2 (mg)	Niacin B3 (mg)	Total folates B9 (μg)	Magnesium Mg (mg)	Manganese Mn (mg)	Phosphorous P (mg)	Iron Fe (mg)	Zinc Zn (mg)	Sodium Na (mg)	Calcium Ca (mg)
Kodo millet	0.29	0.2	1.49	39.49	122	0.33	101	2.34	1.65	3.35	15.27
Kutki/ Little millet	0.26	0.05	1.29	36.2	91.41	0.23	130	1.26	1.82	4.77	16.06
Proso millet	0.2	0.18	2.3	0	153	0.6	206	0.8	1.4	8.2	14
Finger millet	0.42	0.19	1.1	18.3	137	5.49	283	3.9	2.3	11	344
Foxtail millet	0.59	0.11	3.2	15	81	0.6	290	2.8	2.4	4.6	31
Barnyard millet	0.33	0.1	4.2	0	82	0.96	280	5	3	0	20
Pearl millet	0.33	0.25	2.3	45.5	137	1.15	296	8	3.1	10.9	42
Whole wheat flour	0.42	0.15	2.37	29.22	125	2.98	315	4.1	2.85	2.04	30.94
Rice (raw) millet	0.05	0.05	1.69	9.32	19.3	0.73	96	0.65	1.21	2.34	7.49

Source: Gopalan et al. [13]; Geervani and Eggum [14]; Longvah et al. [15].

94% of the total area under small millets [21]. In Madhya Pradesh, there are two districts that have the highest area under the state: Dindori and Mandla for the production of kodo and Chhindwara and Dindori for the production of little millets [21].

Kodo millet is an herbaceous plant growing yearly with an adventitious root system that sprouts from lower nodes and produces several thin roots. Branched roots develop laterally and radially, and they continue to function throughout their lives. The stem is robust, occasionally growing to a height of 60–90 cm, and is tangled on a short rhizome. Swollen nodes and totally clad internodes characterize this glabrous stem. At a later phase, nodal bands turn purple. Kodo millet flowers are small and inconspicuous by nature and self-pollinated; therefore, they remained unopened. Seeds are harvested in the period of June to July and also in between February and March. To maintain the quality and effectiveness of seed development, rain must not hinder the process of pollination [22]. The grain size of kodo millet is 2.5 * 2.0 mm with an approximate kernel weight of 4 g and oval in shape, and the colour varies from light brown to dark grey [4]. Kodo millet is a good source of polyphenols, flavonoids, and antioxidant compounds [23]. Due to its richness in nutritional parameters, kodo has many health benefits. Its richness in phytochemicals and phytates makes it anticancerous and helps to reduce body weight and knee and joint pains/arthritis [8]. The extracts from kodo millet grains have strong *in vitro* antioxidant potential, whereas the whole grains are demonstrated to have an antidiabetic effect in diabetic rats induced with alloxan [23] and improve

Table 3: Amino acid profile of millets compared to cereals.

Cereals and millets	Parameters												
	Arginine (mg)	Tryptophan (g)	Histidine (g)	Phenylalanine (g)	Lysine (g)	Tyrosine (g)	Cystine (g)	Threonine (g)	Valine (g)	Leucine (g)	Isoleucine (g)	Methionine (g)	Glutamic acid (g)
Kodo millet	3.18 g	1.32	2.14	6.27	1.42	—	1.92	3.89	5.49	11.96	4.55	2.69	18.25
Kutki/little millet	5.96 g	1.35	2.35	6.14	2.42	—	1.85	4.24	5.31	8.08	4.14	2.21	20.22
Proso millet	290	50 mg	110 mg	310 mg	190 mg	—	—	150 mg	410 mg	760 mg	410 mg	160 mg	
Finger millet	300	100 mg	130 mg	310 mg	220 mg	220 mg	140 mg	240 mg	480 mg	690 mg	400 mg	210 mg	
Foxtail millet	220	60 mg	130 mg	420 mg	140 mg	—	100 mg	190 mg	430 mg	1040 mg	480 mg	180 mg	
Barnyard millet	270	50 mg	120 mg	430 mg	150 mg	—	110 mg	200 mg	410 mg	650 mg	360 mg	180 mg	
Pearl millet	300	110 mg	140 mg	290 mg	190 mg	200 mg	110 mg	240 mg	330 mg	750 mg	260 mg	150 mg	
Whole wheat flour	290	0.99	2.56	5.03	2.42		2.24	2.58	5.12	6.13	3.78	1.77	29.61
Rice (raw) milled	480	1.27	2.45	5.36	3.7		1.84	3.28	6.06	8.09	4.29	2.6	18.92

Source: Gopalan et al. [13]; Geervani and Eggum [14]; Longvah et al. [15].

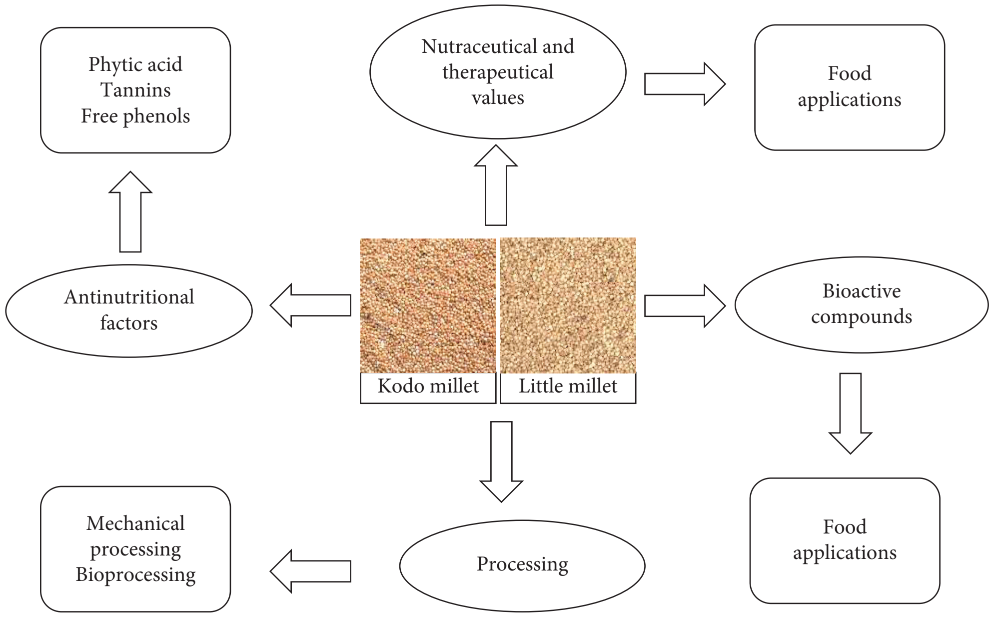

Figure 1: Applications of kodo and little millets.

neurological disorders. Srinivasan et al. [24] reported an immunostimulant and immunomodulatory response in little and kodo millet, respectively, in RAW 264.7 cells. Seed-born head smut is a type of disease, which is reported to be widespread for few years. To avoid or prevent the seeds from the disease, they are soaked in 1.5% concentration of copper sulphate or dusted with copper carbonate (6 g/kg). Also, Dithane M45 [mancozeb], Parasan [phenylmercury acetate], and Bavistin 25 SD [carbendazim] at a concentration of 2 g/kg seed could be used for best results [22].

Little millets known as saamai or kutki are short-duration millets and withstand both drought and waterlogging (Figure 1). Little millet is also a yearly crop having 30–90-cm hollow jointed stem with slender and robust base. The leaves are linear and can be 15–50 cm in length to 12–25 cm in breadth, while the nodes are glabrous. The seeds are grown during the period from June to July or between February and March [22]. Its grain size is approximately 2.5 * 1.5 mm with 1.9 g of approximate kernel weight oval in shape, and the colour is creamy with shiny appearance [4]. "Cool food" is another name for little millet because of the cooling impact it has on the body when consumed in summer time [25]. Little millet just like every other millet is nutritionally better than the cereals, although its consumption is confined. Nutraceuticals including resistant starch, phytates, phenolics, sterols, lignans, and gamma-aminobutyric acid are also prominent in little millet [26]. Kushwaha et al. [27] notified that substantial retention of phytates has a beneficial effect on health due to the antidiabetic and anticancerous properties and acts as antioxidants. It helps to prevent constipation and heals most of the stomach problems. Its significant high fiber content aids in the reduction of fat deposits in the body [8] and is also responsible for the movement of food and waste through the digestive system [28]. The drudgery connected with its processing and palatability are the main factors deterring its cultivation and consumption. This creates a need to rekindle interest in millets due to their potential nutritional qualities and health benefits [29]. The dietary fiber content of kodo and little millet is higher than that of cereals (37–38%); the fat content is more in polyunsaturated fatty acids (PUFA) [30]. Some species of little millet appear faintly yellowish in colour, confirming the existence of carotenoids. The total carotenoid content of little millet was reported to be between 51 and 104 μg/100 g as per Guha et al. [26]. Shoot fly and rust (caused by Uromyces linearis) are the two kinds of diseases found in little millets. Shoot fly could be treated with carbofuran with azotobacter biofertilizer or the application of phorate (1 kg a.i/ha) in the soil [22].

Kodo and little millets are produced widely and consumed in various states of India. The production pattern and their consumption show that millets are gaining their importance and people are trying to follow healthy diet charts. Madhya Pradesh has the largest area for small millet cultivation followed by Chhattisgarh, which covers 19.5% of land, Uttarakhand 8%, Maharashtra 7.8%, Gujarat 5.3%, and Tamil Nadu 3.9%. The productivity of millets is higher in Uttarakhand, which accounts to be 1174 kg/ha, followed by Tamil Nadu (1067 kg/ha) and then Gujarat (1056 kg/ha). The state of Karnataka has the most land and produces the most finger millet, followed by Tamil Nadu. Karnataka alone accounted for roughly 66% of overall production, whereas other states in India produce very little. However, Tamil Nadu has the highest finger millet production (2464 kg/ha), followed by Karnataka (1782 kg/ha), both of which are higher than the national average yield (1580 kg/ha) [31]. Chouhan et al. [21] found that the average yield of kodo and little was 2.77 and 2.71 quintal per acre, respectively, as compared to 0.14 and 0.12 quintal per acre in the year 2018. A regular farmer used around 40% of the total produce of both crops. In the case of kodo and little, farmers preserved 5.42 and 3.69 percent of total yield for seed and 0.72 and 0.55

percent for animal feed, respectively, and wastage of kodo and little millets was determined to be 1.81 and 3.95 percent of total production, respectively. According to the analysis, the marketable excess is greater than the marketed surplus. The disposal pattern of kodo and little for marketed surplus was observed during 2015–16, with data showing that an average manufacturer sold 78.30% kodo and 72.14% little of marketed surplus in the peak periods from September 2015 to March 2016 with an average cost of Rs. 18.71 and Rs. 19.47 per kg, respectively. During the lean period, the remaining 21.70% kodo and 19.47% little were sold at average costs of Rs. 22.36 and Rs. 23.40 per kilo, respectively. The selling cost of kodo and little millet was determined to be Rs. 20.23 for kodo and Rs. 21.11 for little millet per kilogram, with prices ranging from Rs. 15 to Rs. 24 and Rs. 7 to Rs. 25 per kilogram. This suggested that the price and quantity of kodo and little millet sold in the market were inversely related [21]. According to unit level NSSO, the consumption pattern for small millets was obtained for rural and urban areas in India through the 68th round on "Employment and Unemployment" and "Household Consumer Expenditure." The result shows that the consumption of small millets in Assam (18.82 kg/hsh/m) and Bihar (18.69 kg/hsh/m) recorded was the highest, whereas other states consume less than 10 kg per household per month [31].

Millets contain antinutrients such as phytates, phenols, tannins, trypsin inhibitory factors, and dietary fiber, which chelates metals and impedes enzymes [32]. The phytates, phenols, and tannins have become known to contribute to antioxidant activity, which is significant in health, ageing, and metabolic diseases [33]. Antinutritional components constitute organic molecules found in food that prevent minerals, dietary proteins, and carbohydrates from being digested, utilized, and available. They can be found in plant and animal diets as natural elements, artificial components added while processing, or ecological pollutants. Some of these components include tannins, trypsin or protease inhibitors, saponins and haemagglutinin, phytates or phytic acid, oxalates or oxalic, glucosinolates, and gossypol [34]. Table 4 shows the antinutrient compounds found in different millets. Many antinutrients, such as oxalate or cyanogenic acid, may be hazardous above a certain level in addition to their primary effects on nutrient absorption. As a result, it is critical to eliminate these factors [35]. Phytates and tannins are the antinutrient components found specifically in kodo and little millet.

Table 4: Antinutrient compounds found in millets.

Millets	Antinutrients	
	Phytic acids	Tannins
Kodo millet	1.2–1.4 $mg \cdot g^{-1}$	1.0–1.2 $mg \cdot g^{-1}$
Little millet	—	332.1–336.8 mg CE/100 g
Barnyard millet	3.37–3.70 $mg \cdot g^{-1}$	—
Proso millet	7.2 $mg \cdot g^{-1}$	—
Finger millet	5.54–5.58 $mg \cdot g^{-1}$	3.5 $mg \cdot g^{-1}$
Pearl millet	9.2 $mg \cdot g^{-1}$	2.2 $mg \cdot g^{-1}$

Source: [2, 26].

3. Antinutritional Constituents in Kodo and Little Millets

3.1. Phytic Acid. Antinutritional components such as phytate are subdivided into phytic acid myoinositol, which are a 1,2,3,4,5,6-hexa dihydrogen phosphate, that store 1–5% of phosphorous by weight in cereals, nuts, and legumes [36]. In addition, 50–85% of phosphorous is incorporated in plants externally [37]. Phytic acid is present as crystalline globoid inside protein bodies in the cotyledon of oilseeds and legumes and in the bran portion of cereals. They are negatively charged structure due to which they attract the positively charged substances like minerals (Zn, Ca), forming insoluble complexes that are unavailable for digestion and absorption. Also, phytic acid reacts indirectly with the negatively charged group of proteins mediated by a positively charged mineral ions, which make protein undigestible to some amount [38]. Various studies indicate phytate cannot be digested by people nor nonruminant beings; therefore, it cannot be considered a source of inositol or phosphate when consumed directly. The concentration of phytic acid and tannin in different varieties of kodo millet ranged from 1.2 to 1.4 and 1.0 to 1.2 mg/g, respectively [2]. Phytates form chelates with di- and trivalent metallic particles, such as Cd, Mg, Zn, and Fe, to produce poor soluble compounds, which are not absorbed from the gastrointestinal tract, resulting in decreased bioavailability [39], and hence considered antinutritive agent. Cereals, legumes, oilseeds, and hard-shelled fruits, which are vital in nourishment, are the sources for phytic acid (Figure 2). A concentration of 126.91 mg/100 g of phytic acid was reported in kodo millet by Shyam and Singh [34].

3.2. Tannins and Free Phenolics. Tannins and free phenolics are two more antinutrient groups found in foodstuffs. The two tannins, as well as several free phenolics, are not suitable for human consumption. Tannins prevent protein from being digested [40]. Furthermore, phenolic compounds reduced the digestibility of proteins and carbohydrates, as well as the bioavailability of vitamins such as vitamin B12 and minerals [41]. They additionally diminish actions of digestive enzymes such as trypsin, chymotrypsin lipase, and α-amylase. Tannins take two forms based on their ability to dissect hydrolytically with hot water, acids and alkali, or enzymatic action: condensed and hydrolysable [42]. Hydrolysable tannins are susceptible to digestive hydrolysis, which might result in toxic substances, whereas condensed tannins are nonhydrolysable and not assimilated during digestion [2]. The majority of condensed tannins are flavan-3-ols, which are catechins, or flavan 3 : 4 diols, which are leucoanthocyanidins, whereas the majority of hydrolysable tannins include glucose or polyhydric alcohol esterified with gallic acid (gallotannins) or hexahydrodiphenic acid (ellagitannins). Ellagic acid is the stable dilactone of the latter [38]. Protease inhibitors, like trypsin inhibitors, generate pancreatic hyperplasia, which affects sulphur metabolism, hence lowering protein digestibility due to the ineffective utilization of other amino acids [2]. Tannin (Figure 3) is a

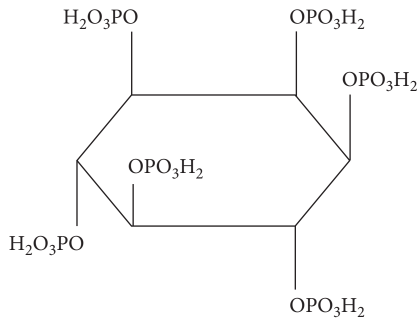

Figure 2: Structure of phytic acid.

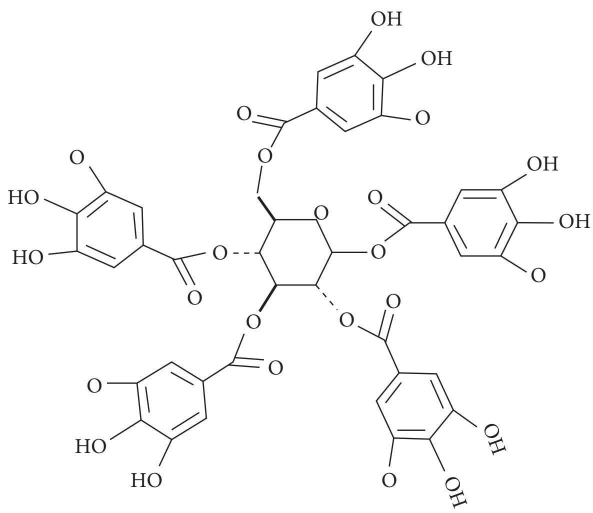

Figure 3: Chemical structure of tannin.

bitter, astringent polyphenolic molecule found in plants that binds and precipitates proteins as well as other organic components such as amino acids and alkaloids. The sensitivity of tannins for different proteins varies, with proteins rich mostly in imino acid proline, like collagen of animal tissues as well as the alcohol-soluble reserve proteins of plant origin. As these proteins lack essential amino acids, tannins have a less detrimental impact on protein digestion than when tannins bind nonpreferentially or primarily to proteins rich in essential amino acids [38]. The tannin compounds are widely distributed in a variety of plants, and they are used as insecticides and in-plant growth regulators, as well as to guard against predators. Tannins are customarily considered antinutritional; however, in the present scenario, it has been realized that their favourable or antinutritional characteristics rely on their synthetic structure and dosage [43]. The acid treatment advances the build-up of polyphenols just as hydrolysis. The two sorts of vegetable tannins display the capacity to form complex and precipitate proteins. In this manner, both are nutritionally risky. The condensed tannins are boundless in organic products, vegetables, scrounge plants, red wine, and particular food grains, for example, sorghum, millets, and vegetables [44]. The intake of tannins results in depression along with reduction in digestive enzymes, enhanced production and secretion of endogenous protein, digestive tract malfunctions, and toxic effects of ingested tannin and its metabolites. Various medical studies connected dietary tannins to an elevated risk of oral esophageal cancer [38]. It is important to remember that food processing practices can break down phytic acid. Soaking in an acidic media, lactic acid fermentation, and sprouting are all effective methods [43]. The tannin content and total phenol were reported as 124.75 and 19.5 mg/100 g, respectively, in kodo millet as reported by Shyam and Singh [34].

4. Bioactive Compounds in Kodo and Little Millets

For life and subsistence, every living organism, whether a single-cell bacterium or a million-cell plant, creates a variety of chemical substances. The biological system's components can be categorized into two categories: primary metabolites that are chemical compounds just like carbohydrates, proteins, amino acids, and lipids that aimed at growth and development, and secondary metabolites that are bunch of compounds that help plants to escalate their overall potentiality for survival and to overcome the local constraints through their interaction with its environment [45].

Among all the secondary metabolites, some substances have effect on different systems of biology and are regarded as bioactive. Ergo bioactive compounds found in plants may be described as "Secondary plant metabolites eliciting pharmacological or toxicological effects in human and animals" [46].

Bioactive compounds are available in small amounts in foods, predominantly in whole grains, fruits, and vegetables and also give health advantages in addition to nutritional value (Gökmen, [47]. The bioactive compounds have therapeutic potential as well as an effect on energy intake, which reduces pro-inflammatory state, oxidative stress, and metabolic diseases [48]. Epidemiological information indicates intake of various kinds of foods that are rich in bioactive compounds and antioxidants such as vitamins, phytochemicals, and predominantly phenolic compounds such as flavonoids and carotenoids in high amount; shows its positive impact on health; and may help reduce the risk of various ailments, such as cancer, Alzheimer's, cataracts, heart disease, stroke, diabetes, and age-related functional degeneracy [49]. Bioactive compounds are competent to modulate metabolic processes that exhibit positive possessions such as inhibition of receptor activities, antioxidant effect, inhibition and induction of gene expression, and inhibition or induction of enzymes [50]. The different chemical structures of the bioactive compounds affect bioavailability and biological properties, but antinutritional factors may inhibit digestion enzymes or decrease the bioavailability of specific compounds [51].

The bioactive compounds are divided into (a) alkaloids, (b) terpenes and terpenoids, and (c) phenolic compounds [52]. Most of the bioactive compounds allied to one of various families, and each has specific structural characteristics that arise from the way they are held in nature (biosynthesis). Bioactive compounds or secondary metabolites can be synthesized through four major pathways: (1) malonic acid pathway, (2) shikimic acid pathway, (3) nonmevalonate pathway (MEP), and (4) mevalonic acid pathway [53]. The bioactive components like alkaloids are processed through aromatic amino acids, which further come through shikimic acid pathway and through aliphatic amino acids that is obtained from tricarboxylic acid cycle. Shikimic acid pathway along with malonic acid pathway synthesizes phenolic compounds. Terpenes are synthesized through mevalonic acid pathway and MEP pathway [54].

Oxidative stress is the principal factor for various diseases such as cardiovascular and metabolic disorders, cancer, and CNS-related disorders, and ageing. Among the various food items, grains are rich in minerals (zinc, iron, selenium, etc.), amino acids, vitamins (vitamin E and vitamin C), and phenolic compounds (phenolic acid, coumarins, flavonoid, tannin, etc.), which are included under the head of phytoconstituents. They act symbiotically and negotiate health promotive, preventive, and curative effect. Antioxidant activity is a key mechanism in food grains, and as a result, they are protruding as a therapeutic substance in addition to their nutritional importance [55]. Millets, rice, and wheat are good sources of phenolic constituents, which in turn are well known in antioxidant substances. There are various *in vitro* and *in vivo* studies to confirm its therapeutic effectiveness in curing different ailments such as diabetes, hyperlipidemia, cancer, cardiovascular diseases, and central nervous system (CNS) disorders [55]. Table 5 shows the various bioactive components found in kodo/little millets, which prove their nutraceutical and therapeutic role.

4.1. Phytochemicals. Phytochemicals include biological active, chemical compounds found naturally in different components of plants such as root, stem, leaf, flower, fruit, and seed that provide therapeutic and nutritional benefits for humans [74, 75]. The chemicals that guard plants from disease and environmental threats such as pollution, stress, drought, UV exposure, and pathogenic attack while also contributing to its colour, aroma, and flavour are known as phytochemicals [76, 77]. Recently, evidence has gained prominence suggesting phytochemicals play a role in human health protection when consumed in large quantities [78, 79]. Fruits such as tomatoes, grapes cherries, strawberries, and raspberries; vegetables such as broccoli, cabbage, carrots, onions, and garlic; legumes; whole grains and millets; nuts; seeds; fungi; and herbs and spices are common sources of phytochemicals [77, 80]. The phytochemical compounds exhibit biological characteristics such as antioxidant activity, antimicrobial property, modulation of detoxifying enzymes, stimulating immune system, a reduction in platelet aggregation and modulating hormone metabolism, and anticancer activity [81]. Phytochemicals are classified as primary or secondary metabolites as per their portrayal in plant metabolism. Primary metabolites include the common sugars, amino acids, proteins, purines, and pyrimidines of nucleic acids, and chlorophyll. Secondary metabolites constitute alkaloids, terpenes, flavonoids, lignans, plant steroids, curcumins, saponins, phenolics, and glucosides [82]. Most phytochemicals possess numerous properties that are important for plants and animals. The properties such as antioxidant activity guard the cells from oxidative damage and reduce the possibility to develop certain kinds of diseases like cancer. Phytochemicals with antioxidant activities include carotenoids (found in fruits), flavonoids (found in fruits, vegetables), and polyphenols (tea, grapes) [83]. The antimicrobial properties are prominent with phytochemicals like allicin in garlic, benzophenone, and flavanone in bitter, while some phytochemicals connect to cell walls in physiological way, interfering with pathogens that adhere to cell receptors. Cranberry's anti-adhesion characteristics are due to proanthocyanidins, and their ingestion lowers the risk of infections from urinary tract and maintains oral health [84].

4.2. Phenolics. Phenolic compounds are a broad term, which is characterized by the presence of an aromatic ring with one or more hydroxyl groups and various substituents. Phenolic compounds present in the plant kingdom can be subdivided into many groups such as phytoestrogens (isoflavones), lignans, phenolic acids, and flavonoids. Phenolic acids are the derivatives of benzoic acid (C_6-C_1 structure), that is, *p*-hydroxybenzoic, gallic, syringic, vanillic protocatechuic acid, and other derivatives of cinnamic acid (C_6-C_3 structure), that is, caffeic, ferulic, sinapic, and *p*-coumaric [38], whereas flavonoids contain a basic C_6-C_3-C_6 structure and include the anthocyanin pigments, flavonols, flavonals, and isoflavones [38]. Therefore, all these phenolic compounds serve as a medicine, which provides various health benefits. Opposite to this, tannins are classified as condensed or hydrolysable phenolic compounds, which act as antinutrient to bind proteins to form soluble and insoluble complexes and hence inhibit protein digestion. Those proteins rich in imino acid proline groups are generally bound by the tannins that are available in cereals [38].

Among all the phytochemicals present in millets phenolics are important sources of antioxidants. Phenolic compounds are among the vast category of phytochemicals and are found throughout the plant kingdom [85]. The hydroxyl group is linked directly to an aromatic hydrocarbon group in phenolics. Phenol (C_6H_5OH) is found to be the simplest class of natural compounds and has a significant part of defence because of its secondary metabolite action. Phenolics possess antioxidant properties, which crucially maintain the body's oxidative balance by giving further protection from oxidants, oxidative processes, and reactive species. Despite their chemical diversity, phenolic compounds have the ability to boost the potential of other compounds, inhibit the adverse effects of a few compounds, and acquire new biological features through a chain of polyvalence processes [86]. Little millet cultivars have higher concentrations of phenolics when compared to foxtail millet variety. In little millet grains, the concentration of phenolic compounds may vary on the basis of fractions obtained after milling of grains [71]. Bioactive compounds such as gallic acid, vanillic, *p*-hydroxybenzoic acid, sinapic acid, chlorogenic acid, caffeic acid, ferulic acid, and *p*-coumaric acid are

Table 5: Bioactive compounds found in kodo/little millets.

Bioactive compounds					
Compounds	IUPAC name	Chemical formula	Health benefits	Kodo/ Little	References
Catechin	(2R,3S)-2-(3,4-dihydroxyphenyl)-3,4-dihydro-2h-chromene-3,5,7-triol	$C_{15}H_{14}O_6$	Anticancer, anti-obesity, and helps in treatment for Alzheimer's and Parkinson's disease	Kodo	Khan et al. [56]; shankar et al. [57]; singh et al. [58]
Naringin	7-[[2-O-(6-deoxy-α-L-mannopyranosyl)-β-D-glucopyranosyl]oxy]-2,3-dihydro-5-hydroxy-2-(4-hydroxyphenyl)-4H-1-benzopyran-4-one	$C_{27}H_{32}O_{14}$	Anti-apoptotic, anticarcinogenic, anti-inflammatory, antiulcer, anti-osteoporotic	Kodo	Wang et al. [59]
p-Coumaric acid	(2E)-3-(4-hydroxyphenyl)prop-2-enoic acid	$C_9H_8O_3$	Anti-inflammatory, anticancer, anti-obesity, reduces lipid peroxidation, cholesterol oxidation, and LDP	Kodo	Boz, [60]; Kannan et al. [61]; Ferguson et al. [62]
Taxifolin	(2R,3R)-2-(3,4-dihydroxyphenyl)-3,5,7-trihydroxy-2,3-dihydrochromen-4-one	$C_{15}H_{14}O_6$	Anti-inflammatory	Kodo	Gupta et al. [63]
Ferulic acid	(2E)-3-(4-hydroxy-3-methoxyphenyl) prop-2-enoic acid	$C_{10}H_{10}O_4$	Antithrombotic, anti-allergic, antimicrobial, anti-inflammatory, antiviral, anticarcinogenic, hepta-protective, vasodilatory effect	Kodo	Graf, [64]; Akihisa et al. [65]; Oosterveld et al. [66]; Rukkumani et al. [67]
Sinapic acid	3,5-Dimethoxy-4-hydroxycinnamic acid	$C_{11}H_{12}O_5$	Anticarcinogenic and anti-inflammatory	Kodo	Connelly et al. [68]
Pterin-6-carboxylic acid	2-Amino-4-oxo-3h-pteridine-6-carboxylic acid	$C_7H_5N_5O_3$	Antitumor	Kodo	Hadi et al. [69]
Campesterol	(3S,8S,9S,10R,13R,14S,17R)-17-[(2R,5R)-5,6-dimethylheptan-2-yl]-10,13-dimethyl-2,3,4,7,8,9,11,12,14,15,16,17-dodecahydro-1H-cyclopenta[*a*]phenanthren-3-ol	$C_{28}H_{48}O$	Lowers cholesterol, shows anticarcinogenic and chemopreventive effect	Kodo	Choi et al. [70]
Kaempferol	3,4′,5,7-Tetrahydroxyflavone	$C_{15}H_{10}O_6$	Lowers the risk of chronic diseases	Little	Pradeep & Sreerama, [71]
Luteolin	2-(3,4-Dihydroxyphenyl)-5,7-dihydroxy-4H-1-benzopyran-4-one	$C_{15}H_{10}O_6$	Antioxidant, anti-inflammatory	Little	Pradeep & Sreerama, [25]; Dykes & Rooney, [72]
Apigenin	5,7-Dihydroxy-2-(4-hydroxyphenyl)-4H-chromen-4-one	$C_{15}H_{10}O_5$	Antidiabetic, antirheumatic, anticancerous	Little	Thakur & Tiwari, [73]

all rich in little millets [17]. Herbal therapy is thought to work through synergism and a multimodal system, working through numerous paths or possibly by multiple entities repeatedly hitting a target [87]. As a result, the existence of phenolics possessing antioxidant properties supports plant-based bioactivity in the administration or curing of various diseases through therapeutic synergism [88]. However, water-soluble phenol and peroxidase are responsible for the off odor of millets flour during storage [89]. The three major groups of dietary phenolics are flavonoids (apigenin, quercetin, catechin, and taxifolin), phenolic acids such as hydroxybenzoic and hydroxycinnamic acid (vanillic acid, gentisic acid, syringic, and protocatechuic acid; cinnamic acid, sinapic acid, *p*-coumaric acid, and ferulic acid) and polyphenols [90, 91].

Polyphenols are micronutrients obtained through certain plant-based foods, which are affluent in antioxidants and have propensity for health benefits. These focus on improvement or assistance in the treatment of digestion issues, cancer, osteoporosis, weight management difficulties, diabetes, neurodegenerative disease, and cardiovascular diseases [92]. Polyphenols present in quinoa [93], lignans found in flaxseed [94], and lignan amides in hempseed [95], are some examples that may offer a variety of health benefits.

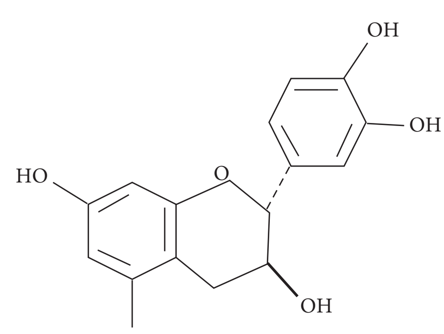

Figure 4: Chemical structure of catechin.

4.3. Catechin. Catechin is a flavonoid, a major antioxidant present in almost all plants especially in tea (Figure 4) [96]. In earlier studies, it was reported to prevent cancer therapy, which induces cell cycle arrest, apoptosis, inhibition of proliferation and inflammation, angiogenesis, metastasis, epigenic modifier, proteasomal activity, and validate gene target [97]. Epicatechin-3-gallate is a major catechin compound that showed beneficial effects in earlier reports of diabetes, Parkinson's disease, Alzheimer's disease, obesity, and stroke [56–58]. Khare et al. [98] quantified 1.10 ppm concentration of catechin in kodo millets, which showed anti-obesity effects.

4.4. Naringin. Naringin is a flavanone glycoside and a source of bioactive compound in citrus fruits (Figure 5) [99]. It possesses anti-apoptotic, anticarcinogenic, anti-inflammatory, antiulcer, anti-osteoporotic, and antioxidant activity [59]. Naringin increases the alkaline phosphatase (ALP) activity [100], osteocalcin [101], and osteocalcin activity [102]. Khare et al. [98] reported 11.97 ppm quantity of naringin in kodo millets with various health benefits.

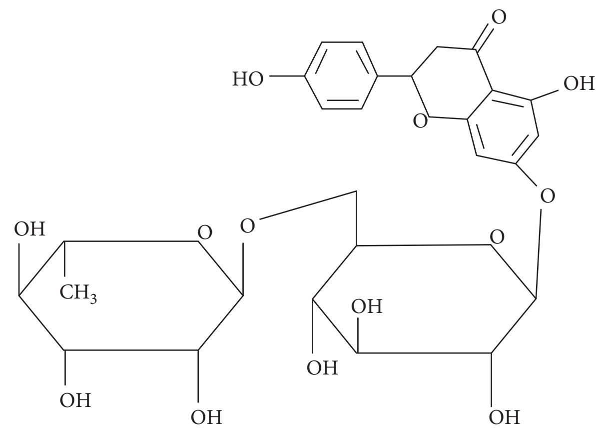

Figure 5: Chemical structure of naringin.

4.5. P-Coumaric Acid. *P*-Coumaric acid is one of the isomer of coumaric acid, which is a hydroxy derivative of cinnamic acid found in edible plants as a component of lignins and tannins (carrot, tomatoes, and cereals) [60]. *p*-Coumaric acid (Figure 6) is a phenolic acid found in bound form in cereals and becomes free by various processes such as fermentation, thermal, pasteurization, and freezing [103]. It acts as antioxidant [60], anti-inflammatory [61], and anticancer [62], reduces lipid peroxidation, cholesterol oxidation, and low-density lipoprotein [60]. Khare et al. [98] quantified 1.38 ppm *p*-coumaric acid in kodo millets with reducing obesity.

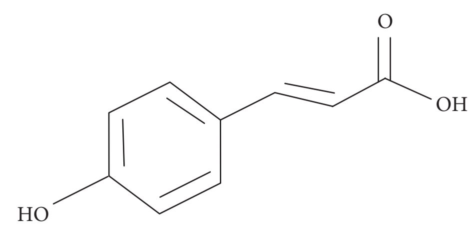

Figure 6: Chemical structure of p-coumaric acid.

4.6. Taxifolin. Taxifolin (3,5,7,3,4-pentahydroxy flavanone or dihydro quercetin) present in citrus fruits or onions is a subgroup of flavonol of flavonoids (Figure 7) [104]. Topal et al. [104] reported that taxifolin inhibits the lipid peroxidation and acts as antioxidant. Taxifolin has two aromatic rings, each with two phenolic groups (-OH) at the meta and para-positions. The strong antioxidant capacity of phenolic compounds is largely determined by the order in which they are arranged [104]. Gupta et al. [63] found that taxifolin possesses anti-inflammatory activity on the exudative and the proliferative phases of inflammation in albino rats.

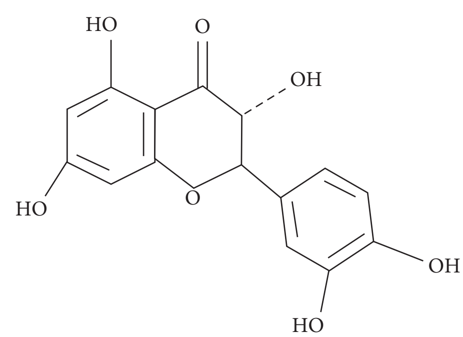

Figure 7: Chemical structure of taxifolin.

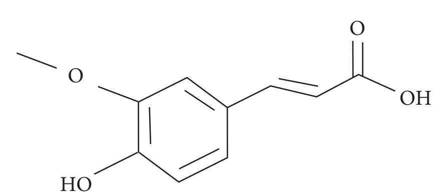

Figure 8: Chemical structure of ferulic acid.

4.7. Ferulic Acid. Ferulic acid (4-hydroxy-3-methoxycinnamic acid) is a phenolic derivative of cinnamic acid found in cereals, vegetables, fruits, flowers, leaves, beans, seeds of coffee, artichoke, peanuts, and nuts (Figure 8) [105]. Ferulic acid showed a broad range of health benefits such as antioxidant, antithrombotic, anti-allergic, antimicrobial, anti-inflammatory, antiviral, anticarcinogenic, hepta-protective, and vasodilatory effect and helps to increase the viability of sperms [64–67]. The unsaturated side chain in ferulic acid and existence of both *cis* and *trans* isomeric forms and the resonance stabilized phenoxy radical account for its effective antioxidant activity [105]. Khare et al. [98] found 20.45 ppm ferulic acid in kodo millets.

4.8. Sinapic Acid. Sinapic acid (3,5-dimethoxy-4-hydroxycinnamic acid) is present as free form as well as found in form of esters in cereals, rapeseed, heartwood, citrus fruits,

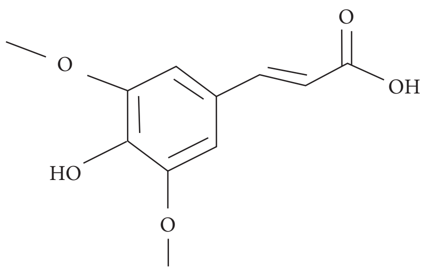

Figure 9: Chemical structure of sinapic acid.

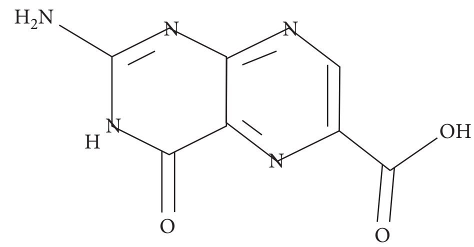

Figure 10: Chemical structure of pterin-6-carboxylic acid.

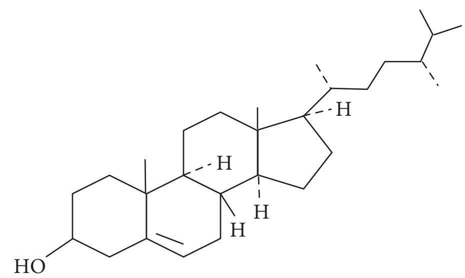

Figure 11: Chemical structure of campesterol.

and Brassicaceae and Rubiaceae species (Figure 9) [106]. Sinapic acid and its derivatives inhibit lipid peroxidation and act as antioxidant, anti-inflammatory, and anticarcinogenic activity [68]. Khare et al. [98] reported 7.9 ppm sinapic acid in kodo millets, which showed an anti-obesity effect.

4.9. Pterin-6-Carboxylic Acid. Folic acid degraded into 6-formylpterin that is further oxidized to pterin-6-carboxylic acid (Figure 10) under ultraviolet radiation and generates reactive oxygen species (ROS) [107]. Sharma et al. [108] reported that raw and germinated kodo millet flour contained 0.5 and 15.84% concentration of phenols, respectively,.

4.10. Campesterol. Campesterol is a common plant sterols in nature found abundantly in cereals, nuts, seeds, vegetable oils, beans, and legumes [109, 110]. The structure of campesterol (Figure 11) is comparable to cholesterol, and likewise, the intestinal bacteria metabolize them, which has cholesterol-lowering benefits [111]. There are various experimental evidences that support the fact that campesterol has a chemopreventive effect against cancers such as breast [112], lung [113], and prostate [114] cancers and performs anticarcinogenic activity [69]. The campesterol concentration in raw and germinated kodo millet flour was determined to be 0.31 and 2.60%, respectively [108].

The phenolic compounds found in kodo millet included methyl vanillate [98], arachidonic amide, N (3,5-dinitropyridin, 2yl) L-aspartic acid ester, N-propyl 9,12,15-octadecatrienoate, pregan-20-one, 2, hydroxyl-5,6 epoxy, 15-methyl, hexadecanoic acid, 9, octadecenoic acid, butyl 6,9,12,15, octadecatetraenoate, hexadecanoic acid, methyl ester, methyl 10-trans, 12-cis octadecadienoate, stigmasterol, C-sitosterol, and pregnenolone [108]. These compounds are identified to have antimicrobial, nematicide, anticancer, antieczemic, carcinogenic, diuretic, antiasthma, amino glycoside antibiotic, antioxidant, anticoronary, hepta-protective, hypocholesterolemic, antistiffness, and activities, remove toxins, reduce fat, and enhance memory anti-inflammatory and trauma factors [108].

5. Effect of Processing on Kodo and Little Millets

Processing technologies are used to develop value-added products that improve the nutritional value and sensory characteristics and enhance the bioavailability of micronutrients. These include soaking, malting/germination, fermentation, and thermal and mechanical processing [27]. These techniques aim at enhancing the bioaccessibility of micronutrients and decreasing the antinutrient content, such as tannin, oxalate, and phytates, and hence, could also be used for the processing of kodo and little millets [115].

5.1. Mechanical Processing

5.1.1. Decortication. Almost all the millets as well as other grains were dehulled using mechanical devices and exposed to various processes, such as hydrothermal treatment and hand-pounding. It has been reported that the dehulling of the millets improves the edible and sensory quality as other cereals [116]. Millets are not easy to decorticate like other cereals; therefore, various treatments are used to decorticate. Hydrothermal treatment hardened the endosperm of the millets and enabled its decortication. Likewise, hand-pounding or other mechanical devices were used, which causes abrasive decortication of the millets [117]. It has been observed that decortication shows no effect on the levels of fat and protein in millets, whereas it dramatically reduced the crude fiber content, minerals, phytochemicals, antioxidant activity, and antinutrients [118]. Chandrasekara et al. [119] showcased that the total phenolic components reduced drastically in kodo and kutki millets after dehulling when compared to whole grain millets due to inconsistent distribution of polyphenolics in distinct layers of the millet grains. Therefore, the nutrient value of millets as functional food was decreased. Nutrients (fiber, minerals, phytochemicals, and antioxidants) and antinutrients are located in pericarp and aleurone layer, which are exfoliated and lead to reduction in their contents [90].

5.1.2. Milling and Sieving. Traditionally, millets were generally pounded by nonmotorized mill, and today, we use electric motorized mill that converts the grains into flour that consists of mainly endosperm portion and removes the bran layer [120]. Due to the separation of the bran layer, it has been observed that the nutrients (minerals, crude fiber, phytochemicals, and antioxidants) and antinutrients significantly decrease but protein and starch digestibility improve. It has also been reported that the proximate composition decreased with an increase in moisture and milling time. Removing the bran portion by sieving also decreases the nutritive value of millets [121]. The quantity of total dietary fiber in debranned millet was found to be 15.9%, demonstrating that even after removing the husk and the majority of the bran, little millet contained considerable levels of dietary fiber [26]. The pulverized finger millet has sharply decreased the fat, fiber, and protein content along with vitamins such as thiamine and riboflavin [122]. Therefore, whole grain flour is recommended, which provides all the nutrients that are beneficial to health.

In conclusion, decortication, milling, and sieving of the millets reduce the nutrient contents as well as antinutrients. Therefore, there is a need for convenient and advanced technology in food industries to produce nutrient-rich millet flour with a maximum yield.

5.2. Bioprocess Technologies

5.2.1. Soaking, Fermentation, Enzymatic Hydrolysis, and Germination. Soaking is one of the easiest methods to reduce the antinutrients from the millets and increases the bioavailability of minerals. It was discovered that soaking whole seeds, decorticated seeds, and flour millets decreased phytate activity and some minerals (iron and zinc). It was also reported that an increase in the soaking time would reduce the minerals contents (phosphorus, calcium, and iron) [123]. It has been reported that polyphenolic compounds also reduced in pearl and finger millet after the activation of the enzyme called polyphenol oxidase [124]. Soaking could improve protein digestibility by removing antinutrients and also improve starch digestibility [125].

Fermentation is the process that changes the biochemical composition (protein, ash, moisture, fat, and fiber) of the millets. In millets, the fermentation process is used to decrease the concentration of antinutrients and increase the protein and starch digestibility. The improvement in protein digestibility is the result of the partial degradation of complex storage proteins to more basic compounds like peptides and amino acids. Nigerian traditional dish made from cereal called ogi is rich in lysine, tryptophan, and vitamin B2 contents, whereas vitamin A and flavonoid contents were reduced [115]. Indian traditional fermented dish called rabadi made from pearl millet was studied for the effect of fermentation on biochemical composition that revealed the increased amount of protein and reduced fat, and crude fiber and also increased the flavonoid content [126]. Fermentation significantly reduces the antinutrients (trypsin, amylase inhibitor, and phytic acid) except tannin. Microbial culture was used for the fermentation of the millets, such as *Saccharomyces diastaticus*, *Lactobacillus brevis*, *Lactobacillus fermentum*, and *Saccharomyces cerevisiae*. The combination of *Lactobacilli* and yeast would increase the protein and starch digestibility. Phytate activity is reduced when pearl millets are fermented with lactic acid [127]. Phenolic compounds of decorticated and cooked grains of various millets (kodo, finger, proso, foxtail, and pearl) were found to be bioaccessible when putting through *in vitro* enzymatic digestion and fermentation through microbes. The amount of protein and crude fat in pearl millet increased, possibly due to protein synthesis through fermentation, while ash, crude fiber, and carbohydrate content decreased, probably due to the leaching of soluble inorganic salts and enzymatic breakdown of fiber throughout fermentation [128]. In other experimental research for pearl millet, reduction in phytic acid and increase in polyphenols during natural fermentation for 72 h have been observed [129]. In finger millet, fermentation enhanced the availability of minerals such as calcium, iron, phosphorus, and zinc, as well as the quantity of vitamins and amino acids [130].

Millet's germination boosted free amino acids and total sugars while decreasing starch content. It enhances the digestibility of protein and starch, which is greater than blanching. It also reduces the antinutrients, such as phytic acid, polyphenols, and tannins. It has been reported that the bioaccessibility of minerals (calcium, zinc, and iron) in millets increased by germination [131]. Germination in pearl millet was found to double the solubility of iron *in vitro*. Germination with probiotic fermentation enhanced the levels of thiamine, niacin, lysine, protein, sugar, soluble dietary fiber, and *in vitro* availability of Ca, Fe, and Zn of food products. Kodo millet has been germinated for 35.82 h and reported a higher phytochemical content (TPC, 83.01 mg GAE/100 g; TFC, 87.53 mg RUE/g) and antioxidant activity of 91.34% of DPPH than that without germination. Also, protein significantly increased from 6.7 to 7.9%, minerals from 232.82 to 251.73 mg/100 g, and dietary fiber from 35.30 to 38.34 g/100 g in the same germinated kodo millet flour [108], whereas the phytate content and tannin content were reduced from 1.344 to 0.997 mol/kg and 1.603 to 0.234 mg/100 g, respectively [108]. Little millets have a lower amount of flavonoids (4.6%) on germination, which could be due to millet's metabolic changes during germination, which leads to the transformation of such secondary plant metabolites. The extractability of flavonoids can be improved by steaming the little millet [26]. Other germinated millets such as barnyard millet showed similar results of phytates decreased from 0.125 to 0.099 mol/kg, and minerals and dietary fibers that significantly increased from 29.9 to 34.79 mg/kg and 21.65 to 23.74% [132]. Foxtail millet's antioxidant activity (59.62% DPPH) seems to be less in germinating flour than kodo millet flour [133]. Sprouting in minor millets lowered the fat, starch, protein, ash levels, and antinutrient contents (phytic acid and tannin), whereas it increased dietary fiber [134].

6. Commercial Importance of Value-Added Products and Its Edible and Nutraceutical Importance

It is well known to us that our ancestors used plant food/extract to cure various degenerative ailments such as diabetes, cancer, metabolic syndrome, and cardiovascular diseases. Furthermore, there is significant evidence that cereals, particularly millets, have numerous health benefits that help to avoid age-related disorders. The bioactive substances, such as phenols, flavonoids, vitamins, minerals, essential fatty acids, and amino acids, are responsible for a variety of medicinal benefits. Other bioactive substances that provide health benefits include lipids, resistant starch, lignans, oligosaccharides, phytosterols, and antinutrients (phytic acid and tannins) [135]. Therefore, millets are accepted as functional foods and nutraceuticals for their ability to prevent cancer and heart and cardiovascular diseases, lower blood pressure and tumor incidences, and helps in curing diabetes and gastrointestinal diseases.

7. Antioxidant Contents

Polyphenols are the most common phytochemicals found in all plant materials and provide a variety of health advantages. Free and bound phenolic extracts of different millet varieties (kodo, little, porso, foxtail, and finger millets) have been found to be high in phenols and have antioxidant properties. Antioxidant activity of millets related to various health benefits such as reduction in cardiovascular disease and diabetes depends upon the variety used [135].

There is very scarce information on the nutraceuticals and antioxidant properties of kodo millet and little millet. In India, the different varieties of millets (kodo, little, finger, barnyard, foxtail, and sorghum) are cultivated and evaluated for radical scavenging activity (RSA) of 1,1 diphenyl-2-picrylhydrazyl (DPPH). It was observed that methanol extract obtained from kodo millet flour showed 70% RSA of DPPH when compared to other millet extracts (15 to 53% RSA) [23]. Antioxidant activity was reduced during the cooking of kodo and finger millet followed by roasting and boiling. The DPPH radical scavenging activity and phytochemical content of kodo millet were reduced when the husk and endosperm were separated. Roasting and steaming little millet after germination raised phenolic, flavonoid, and tannin content by 21.2, 25.5, and 18.9 mg/100 g, respectively, comparable to the unprocessed samples [136]. Thus, antioxidants may be found naturally in kodo and little millet, which can be used as functional food and nutraceuticals in disease reduction. *In vivo* research, on the other hand, should be carried out to verify health benefits.

8. Role of Millets for Diabetics, Cardiovascular Disease, Cancer, Celiac Disease, and Ageing

Hyperglycemia is a symptom of diabetes mellitus, which is marked by changes in glucose, protein, and lipid metabolism. It has been studied that the intake of whole grains reduces the chronic effect of diabetes mellitus. Consumption of finger millet diets lowers the plasma glucose levels than rice and wheat. This could be due to the antinutrients factors that lower the starch digestibility. Also, it has been observed that feeding of millets to the diabetic animals regulates levels of glucose and improves antioxidant levels. In one study, it was reported that finger millets contain phenols, such as gallic, *p*-hydroxy benzoic, vanillin, syringic, protocatechuic, *p*-coumaric, ferulic, trans-cinnamic acids, and quercetin, which reduce diabetes and inhibits the cataract [137]. In another study, feeding of millets to diabetic animals restored the enzymatic (glutathione and vitamins E and C) and nonenzymatic antioxidants (superoxide dismutase, catalase, glutathione peroxidase, and glutathione reductase) [138]. Millets also showed remarkable results on 13 diabetic humans that millets lower their glycaemic index on the consumption of millet-based chapatti [139]. Therefore, millets have the potential to prevent diabetes.

The risk of cardiovascular disease increases due to obesity, smoking, and physical inactivity. Phenolic extracts (0.05 mg/mL) from kodo, finger, proso, foxtail, little, and pearl millets inhibited the oxidation of LDL cholesterol between 1 and 41%. Kodo millet was found to have higher inhibition of lipid peroxidation. Also, feeding of proso millet protein in type 2 diabetic mice improved the plasma levels of adiponectin and high-density lipoprotein (HDL) cholesterol [140]. Therefore, millets may prevent cardiovascular diseases.

Millets containing antinutrients (tannins, phytate) and phenols help in jeopardizing colon and breast cancer in animals as well as esophageal cancer, when compared to wheat and maize. Millets are also beneficial in lowering celiac disease since they are gluten-free, and persons with celiac disease must consume gluten-free grains such as rice, kodo millet, tiny millet, sorghum, corn, oats, pearl millet, and quinoa instead of wheat-, rye-, and barley-based goods [141]. Therefore, millets grains have potential to reduce cancer and celiac disease.

Diabetes and ageing are caused by nonenzymatic glycosylation reactions in between reducing sugars (aldehyde group) and proteins (amino group). It was discovered that a methanolic extract of finger and kodo millets suppressed the glycation reaction, which is important in the prevention of ageing. This could be due to the presence of antioxidants such as phytates, phenols, and tannins [142]. Therefore, millets can be useful to prevent ageing.

9. Traditional Food Applications of Kodo and Little Millets

Various studies reported the use of kodo and little flour for the development of traditional and novel food products, which are discussed next.

9.1. Papad. Papad is prepared from kodo and black gram flour by mixing (1 : 1) both flours and adding cumin seeds, salt, and sodium bicarbonate. The dough is rolled out and sun-dried in a circular shape. The prepared papad is sensorially acceptable and good in texture [143]. In addition, the flavour of papad can be enhanced by adding chilli powder to make it more spicy.

9.2. Vadagam. Vadagam is made by soaking kodo and black gram in a 3 : 1 ratio, then coarsely grinding the ingredients for idly, and fine-grinding for dosa. To add flavour, fenugreek seeds and salt were added, and the concoction was fermented overnight. Furthermore, the batter is used for steaming idly in idly pots and a greased flat pan is used for making dosa [143].

9.3. Thatuvadai. Thatuvadai is deep-fried product prepared from mixture of kodo and Bengal gram flour. To enhance the flavour, salt, curry leaves, chilli powder, and butter are added to the dough, which is then rolled out into a thin sheet and deep-fried in oil [143].

9.4. Muruku (Chakli). To enhance the flavour, kodo flour is mixed with chilli powder, cumin seeds, sesame seeds, asafoetida, butter, and salt. The concoction of all these ingredients is used to prepare dough, extruded out from a hand extruder, and deep-fried in oil [143].

9.5. Kolukattai. Kolukattai is prepared from kodo flour by adding onion, green chilli, coriander leaves, asafoetida, mustard seeds, and black gram and then cooked with continuous stirring to form a dough. The dough is molded into an oval and steamed [143].

9.6. Pakoda and Vadai. Pakoda and vadai are prepared from kodo flour with mixing onion, green chilli, and spices and then deep-fried in oil [143]

9.7. Upama. Roasted kodo rawa is mixed with onion, green chilli, curry leaves, black gram, Bengal gram, and mustard seeds and boiled in water with continuous agitation. Also, sweet products like kesari may be made from roasted kodo rawa by adding milk, sugar, and dry fruits. The coarse kodo flour and wheat flour (2 : 1) are roasted with ghee for halwa, and milk is added during the boiling process [143].

9.8. Adai. Adai is made by soaking kodo millet, rice, black Gram, green Gram, and parboiled rice for 2 hours in a 4 : 1 : 1 : 1 ratio. Chilli powder, asafetida, cumin seeds, salt, and curry leaves are added to the prepared course batter and ground together. A flat greased pan is used to cook the batter. To make sweeten adai, combine kodo millet flour, roasted Bengal gram flour, and green gram flour in a jaggery syrup. To get baked, all flours are put into the produced dough and flattened [143].

9.9. Chapati. To produce khakra, kodo flour and wheat flour (1 : 1) are combined and kneaded with water and salt to make a soft dough that is flattened and roasted on a hot pan, and the flattened dough is roasted until stiff pan bread is obtained [143].

9.10. Adhirasam. Water is mixed with kodo millet flour and rice flour (1 : 1) and set aside for 4 hours. Separately, a flour combination is mixed and fermented overnight at room temperature to make jaggery syrup. The fermented dough is flattened and deep-fried for 2-3 minutes in hot oil [143].

9.11. Cookies. Butter and coconut cookies were created by combining optimized proportions of malted kodo and little millet flour, refined flour, sugar, butter, and coconut powder in three different combinations (25 : 25 : 50, 30 : 30 : 40, and 35 : 35 : 30) of kodo millet flour, little millet flour, and refined flour, respectively [144].

9.12. Kodo Millet-Chickpea Blend. Using kodo millet-chickpea flour blend (70 : 30) processed at a higher screw speed of 293 rpm and a lower feeder speed of 19 rpm, and a medium to high temperature of 123°C, a twin-screw directly expanded snack was developed [145].

9.13. Flakes. Little millet flakes from Millet Garden Cress-Ready to Eat were processed by tempering grains and subjecting them to gelatinization under pressure of 20 to 24 l bs/psi for 20 minutes and then air-cooled for surface dryness. The garden cress seeds were then combined with small millet grains at a 5% level and then ran through a roller with a 0.25 mm gap to make flakes. The flakes were sun-dried before being extruded in a single screw extruder. The strands were broken into grits and dried in the shade for 4 to 8 hours, after which the rolled flakes were roasted for added value [29].

9.14. Bread. Little millet flour was used to replace wheat flour in varied quantities (10, 30, and 50%) in the bread-making process to create a fiber-rich functional loaf [146]

9.15. Kodo-Functional Beverage. Arya & Shakya [147] prepared functional beverage from baryard (7 g), foxtail (10 g), and kodo (8 g) millets along with fructo-oligosaccharides containing ferulic acids and dietary fiber having 1.56 prebiotic activity and a glycaemic index (GI) of 45.07.

10. Conclusions and Future Prospects

The present findings provide information on the nutritional and antinutritional activity of kodo and little millet, which will be helpful to collect the valuable information for the development of functional food and nutraceutical. This may be helpful for the food industry to commercialize the kodo- and little millet-based food items in India as the acceptability of nutrient-rich kodo and little food is scarce among Indian population. Also, nutritional components extracted from kodo and little provide various biologically activities. From the point of future prospects, there is a need to standardize the commercial product prepared and need to optimize the methods for extraction and quantification of biological active compounds.

Kodo and little millets are a good source of dietary fiber and therefore can be utilized for the utilization for the formulation of prebiotics drinks, which helps in digestion. Not only the acceptability of these millets is scarce, but also the food industry does not utilize these to develop functional foods. Also, antinutrients elimination with less time-consuming process can be explored for their utilization in food sectors. There is a need to optimize the methods for extraction, quantification, and purification of bioactive compounds from kodo and little. Toxicity, allergen, and microbial studies will be examined for kodo and little before utilization to develop functional foods. These are the future research area on which studies can be conducted to make available to food sectors to develop functional foods and nutraceuticals.

Data Availability

All data pertaining to this work are available within the article.

Conflicts of Interest

The authors declare no conflicts of interest.

Authors' Contributions

Swarnima Dey helped with conceptualization, investigation, and writing—original draft. Yogesh Kumar and Ayon Tarafdar reviewed and edited the manuscript. Tanushree Maity and Alok Saxena reviewed, edited, and supervised the manuscript.

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